10 August 1966

Materiel Test Procedure 3-2-707*
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

EJECTOR CAM TESTS

1. OBJECTIVE

The objective of this procedure is to evaluate the operation of ejector cams for semiautomatic artillery weapons.

2. BACKGROUND

Modern artillery weapons must be able to maintain comparatively high rates of fire without endangering the operating personnel or equipment. Automatic and semiautomatic weapons permit increased rates of fire, but they also introduce the problem of safely ejecting the cartridge cases so that they will not injure crew members or damage expensive equipment. Several factors control the velocity at which a case is ejected, such as:

a. Design of ejector cam
b. Type of cartridge case (i.e., material - steel, brass - or method of fabrication)
c. Weapon chamber pressure
d. Temperature
e. Weapon type
f. Vehicle reactions
g. Surface finish in chamber of weapon
h. Weapon elevation
i. Counterrecoil velocity

No one ejection velocity criterion applies to all types of weapons. Automatic-type weapons, such as the "Skysweeper" and "Vigilante", require relatively high ejection velocities to properly actuate cycling mechanism; existing tanks, on the other hand, require that the ejected case simply clear the rear face of the breech mechanism and fall, at relatively low velocity, into the spent case bin directly below the gun. Ideally, ejection velocities should be as high as compatible with the design requirements of the weapon.

3. REQUIRED EQUIPMENT

a. Firing Range
b. Applicable Gun Mount
c. High Speed movie camera
d. Recoil length and case ejection markers
e. Electronic Timer
f. Temperature Conditioning Facilities
g. Copper Crusher Pressure Gages

* Supersedes Interim Pamphlet 30-11

4. REFERENCES

A. AR 705-15, Research and Development - Operation of Materiel Under Extreme Conditions of Environment, 4 October 1963.

B. Aberdeen Proving Ground Reports:

1) Nelson, R.H. and Melocik, H.J., Case Ejector Cam Development Tests for 105-mm Gun M68 With Mount M116, Report DPS-426, January 1962.

2) Nelson, R.H., Grepps, P.R., and Uglick, G. V., Proof Acceptance Tests of Mount-Combination M116, With Gun, 105-mm, M68, Report DPS-205, April 1961.

5. SCOPE

5.1 SUMMARY

This Materiel Test Procedure describes the following firing test conducted on ejector cam mechanisms:

Ejection Velocity - A firing study designed to determine under proving ground conditions, the average case ejection velocity under varying conditions of comber pressure and ambient temperature.

5.2 LIMITATIONS

The tests outlined in this Materiel Test Procedure are limited in scope to those items or components in the ejection mechanism that directly influence the ejection velocity of the ejected cases. Aspects not included in this procedure are environmental and service tests.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Experienced gunners shall be available in order to minimize the effect of such variables as backlash.

b. A weapon which has experienced average wear must be available.

c. The tactical mount for which the weapon is designed should be available when it is necessary to conduct tests using some other facility, the carriage reactions should resemble those of the tactical vehicle as closely as possible insofar as they affect cartridge case ejection.

6.2 TEST CONDUCT

6.2.1 Ejection Velocity

a. With the gun in its tactical mount or in an acceptable replacement as defined in paragraph 6.1 (c). Place a high speed camera (1000 frames/sec.),

an electronic timer, and recoil length and case ejection markers, so that the case ejection velocity and mount movement may be recorded.

b. Obtain as many different types of rounds as are available for the weapon. All rounds to be fired shall have inert or minimum charge loaded projectiles.

c. Condition the weapon for 48 hours at one of the following temperatures:

1) Local ambient
2) + 145° F
3) + 125° F
4) + 70° F
5) - 25° F
6) - 65° F

d. Fire the weapon at each temperature and for each type of ammunition in accordance with the elevations and chamber pressures given in Table I. Before each firing measure the height of the tube center line at each gun elevation.

Table I

No. of Rounds	% RMP	Elevation	Data Recorded
1	50	Zero	a through h below
1	75	Zero	
2	100	Zero	
2	115	Zero	
2	100	Intermediate	
2	115	Intermediate	
2	100	Maximum	
2	115	Maximum	
2	100	Zero	

e. Record data with the instrumentation indicated in step a.

6.3 TEST DATA

6.3.1 Ejection Velocity

Record the following for each test run:

a. Recoil length (mechanical marker) in feet.
b. Recoil cycle time (electronic timer) in sec.
c. Chamber pressures (copper crusher type gage) in psi.
d. Case ejection velocity (high-speed movies) in ft/sec.
e. Case ejection distance in feet
f. Case extraction distance (if applicable)
g. Vehicle hop as in MTP 3-2-816.
h. Breech lock action and mount movement (high-speed movies) to be recorded during the local ambient
i. Height of tube centerline in feet
j. Gun elevation in degrees

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Acceptance Case Ejection Velocity Limits

The case ejection velocity should be as high as feasible without creating a safety hazard to the gun crew and, if possible, without requiring the use of an absorption blanket to the rear of the gun. Obviously, the maximum velocity limit will depend on the type vehicle and, in particular, the distance from the rear face of the breech ring to the nearest obstruction in the ejection path of the cartridge case. In the case of the 105-mm gun M68 (Ref. 2a), acceptable ejection velocity limits were determined as 3 to 12 feet per second. These limits are recommended in general for artillery weapon design when no exceptional specifications apply. Again, optimum velocity limits should be verified by tests for each weapon system during engineer design.

6.4.2 Computed Case Ejection Velocity

Approximate case ejection velocities may be computed from the formulas that follow, where

D = Horizontal distance of case from perpendicular dropped from rear face of tube

h_o = Height of tube centerline (with gun at zero elevation) above ground
h = Vertical distance of case, at any instant, below extended horizontal centerline of bore, when gun is at zero elevation
V_o = Initial case velocity
θ = Gun elevation
g = Acceleration of gravity
t = Time (seconds)

The equations of motion for the ejected case are:

Subject to initial conditions:

$$\frac{dD}{dt} = V_o \cos\theta \qquad (1\underline{a}) \qquad D_{(t = 0)} = 0$$

$$\frac{d^2h}{dt^2} = g \qquad (1\underline{b}) \qquad \frac{dh}{dt}_{(t = 0)} = V_o \sin\theta$$

$$h_{(t = 0)} = 0$$

Integration of these, taking into account the assigned initial conditions, gives:

$$D = (V_o \cos\theta)t \qquad (2\underline{a})$$

$$h = \frac{gt^2}{2} + (V_o \sin\theta)t \qquad (2\underline{b})$$

Elimination of t yields the equation for the parabolic trajectory of the ejected case,

$$h = \frac{gD^2}{2V_o^2 \cos^2\theta} + D\tan\theta \qquad (3)$$

The origin for h and D being the location of the case prior to ejection.

For ground impact, $h = h_o$ and $D = D_1$, so that equation (3) solved for V_o in terms of the ground impact coordinated h_o, D_i, is

$$V_o = D_i \left[\frac{g}{2h_o \cos^2\theta - D_i \sin\theta \cos\theta}\right]^{1/2} \qquad (4)$$

This equation gives V_o, the initial velocity of case ejection, in terms of the observed ground impact coordinates h_o, D_i, and the angle of quadrant elevation, θ, ignoring second order effects caused by factors such as air density. For the special case of $\theta = 0$ (gun fired horizontally), $\cos\theta = 1$, $\sin\theta = 0$, and equation (4) reduces to

$$V_o = D_i \left[\frac{g}{2h_o}\right]^{1/2} \qquad (5)$$

As an example, in (4$\underline{a}$) take $h_o = 5$ feet and $D_i = 7$ feet. Then from (4$\underline{a}$),

$$V_o = \frac{7}{\left[\frac{2 \times 5}{32}\right]^{1/2}} = 12.6 \text{ fps.*}$$

* Refer to Figure 4 for plot.

The above method for computing case ejection is approximate only, and should not be substituted for actual (high-speed movie) measurements at the commencement of an engineering test program. The computed velocities can be expected to be within 10 percent of the true velocities, being more accurate at the higher ejection velocities (i.e., above 11.0 fps). A list of typical computed and actual velocities follows for comparison.

Computed, fps	Actual, fps
10.3	11.6
10.1	10.8
10.7	11.2
13.3	13.2
15.1	15.1
17.1	17.0

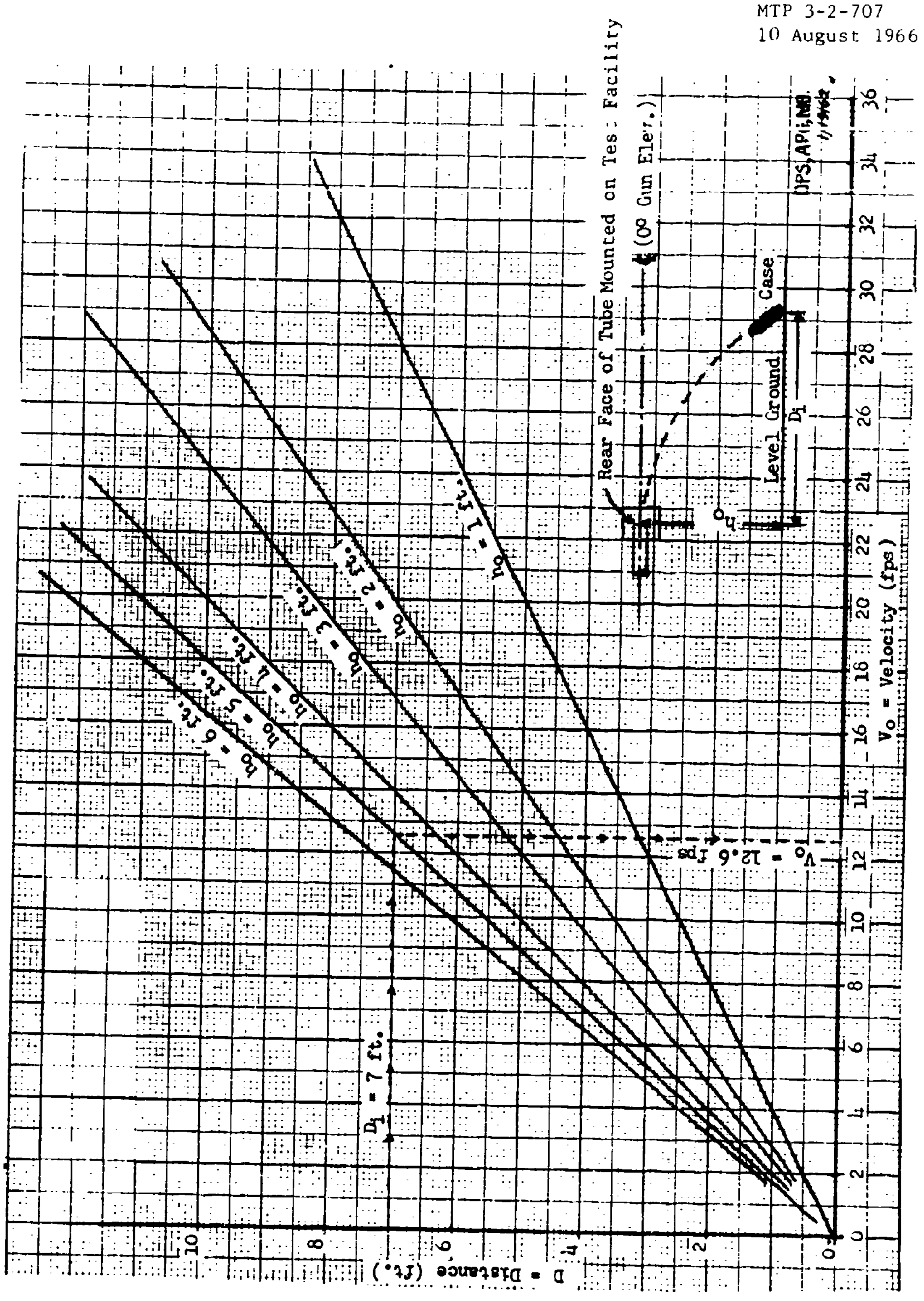

Figure 4. Approximate Case Ejection Velocity

APPENDIX A

TYPICAL PROBLEMS ENCOUNTERED IN AN EJECTOR CAM TEST

Testing Facility

The ideal testing facility would be the tactical vehicle for which the weapon is designed. When it is necessary to conduct tests using some other facility, the carriage reactions should resemble those of the tactical vehicle as closely as possible insofar as they affect cartridge case ejection. For example, in testing the 105-mm gun M68, the 155-mm gun carriage M1 was used instead of the M60 tank. It was found that, by removing the bogies of the 155-mm gun carriage M1, a much higher percentage of cases failed to eject. With the bogies, however, (thus placing added weight forward of the trunnions), cartridge case ejection phenomena closely paralleled that of the M60 tank (Ref. 2a). Typical motion of the various testing facilities is shown in Figure A-1.

Design of Ejector Cam

Cartridge case ejection velocities may be increased or decreased by changing the contour of the camming surface over which the breechblock crank rides and by varying the length of the cam measured from the centerline of the hinge support to the camming surface (Fig A-3). Generally speaking, the steeper the slope of the camming surface, the higher the case ejection velocity. The latest type production cam used on the M140 mount (M601A tank) is shown in Figure A-2.

Type of Cartridge Case

The type of metal and method of fabrication of cartridge cases often influence the velocity of ejection because of different coefficients of elasticity and friction.

Weapon Chamber Pressures

The gas pressures developed by the propelling charge determine, to varying degrees, the extent of cartridge case expansion (i.e., swelling) during firing. Cases that expand close to or beyond their limits of elasticity tend to cling to the interior walls of the chamber, thereby increasing the forces required to eject the case. Rounds fired at excess pressure often fail to eject completely; in other words, the case extracts only. (Note: The terms "ejection" and "extraction" should not be confused. A case is said to be "ejected" when it completely clears the breech ring and falls to the ground or turret floor. It is said to be "extracted" when it is pulled partially out of the chamber but still remains resting on the breech mechanism).

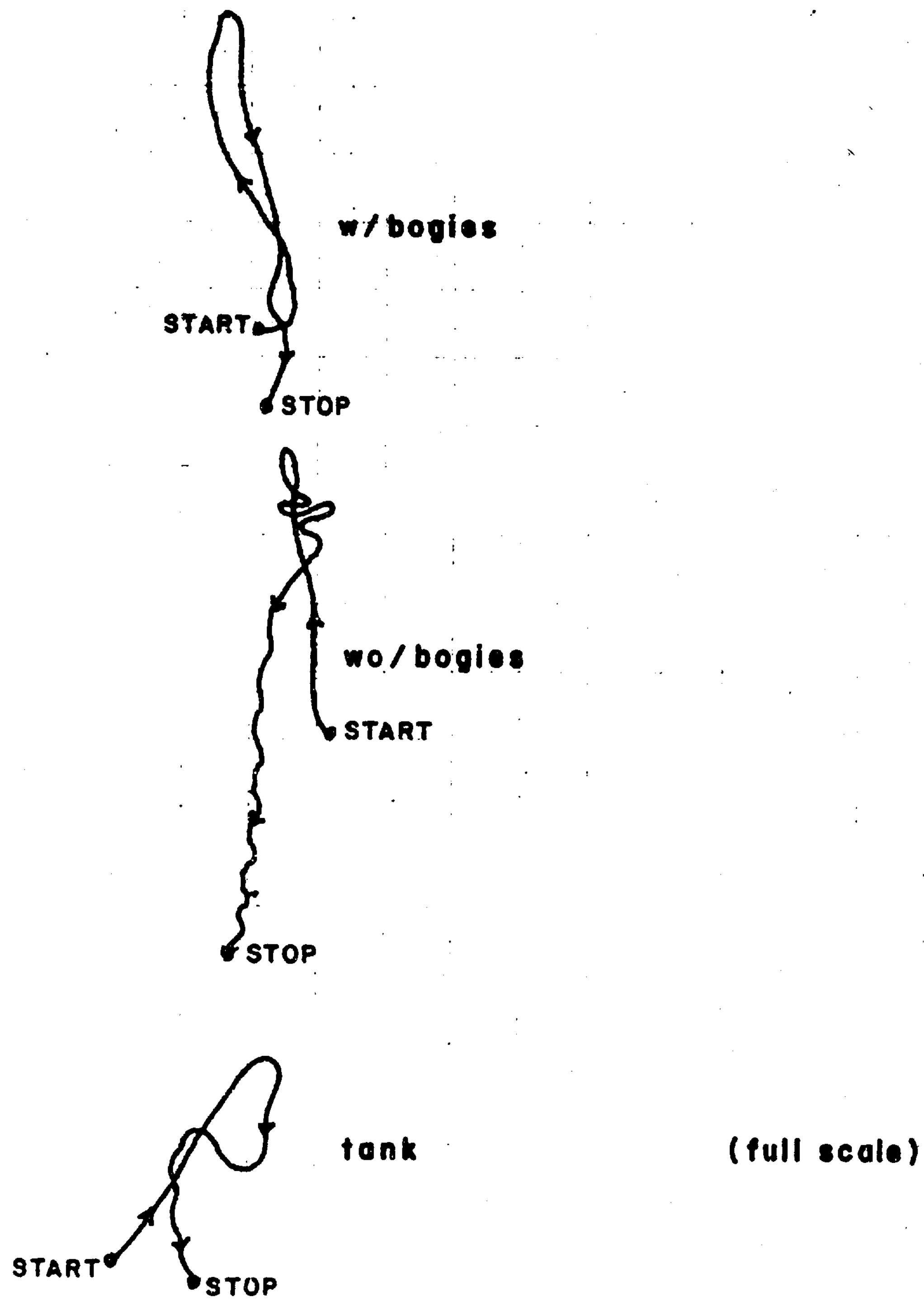

Figure A-1. Typical Hop Records (Carriage Versus Tank)

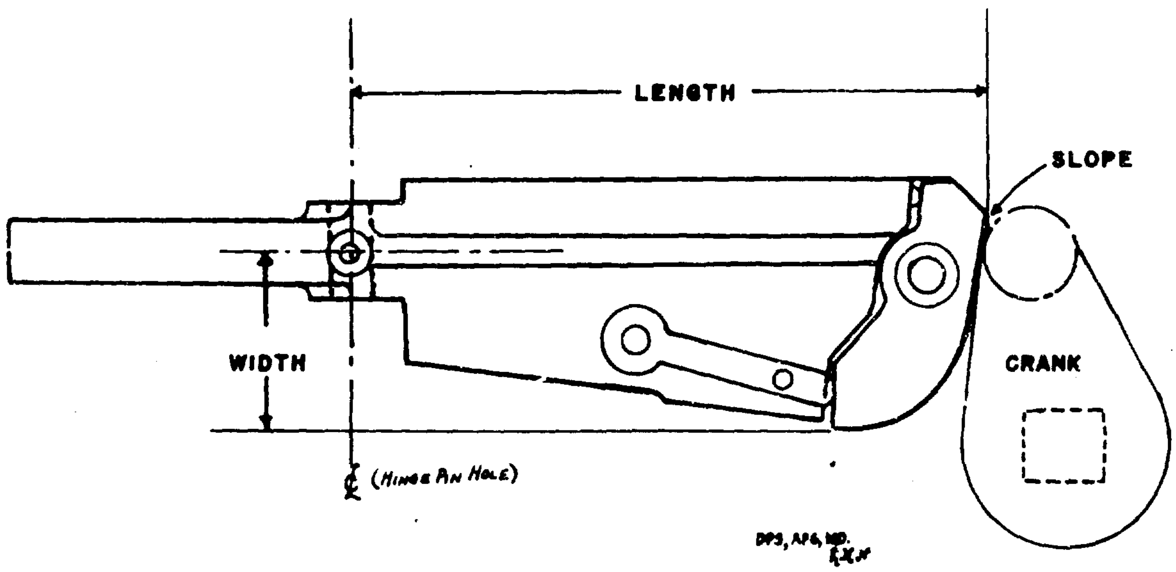

Figure A-2.Cam Critical Dimensions

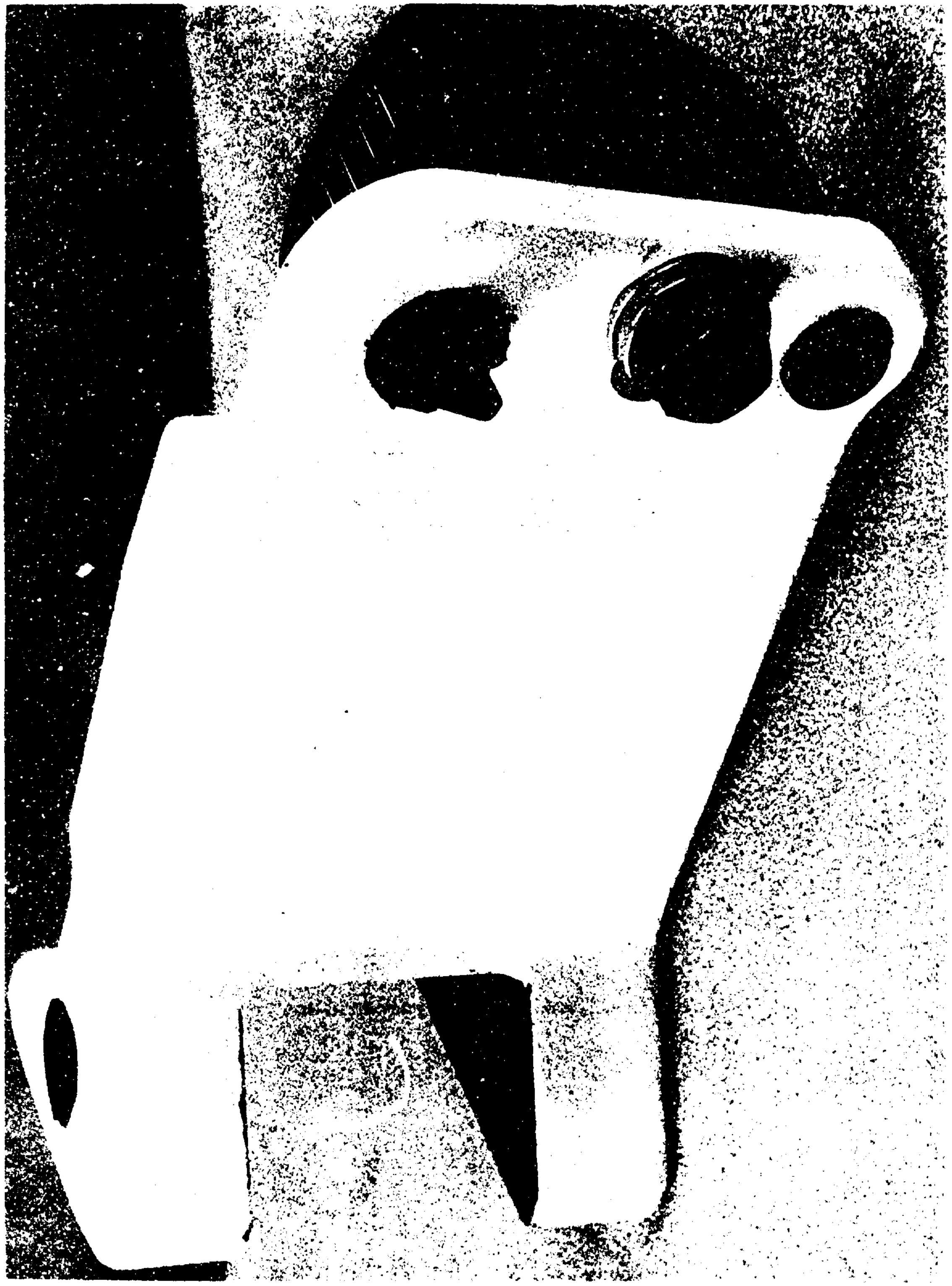

Figure A-3. Variable Cam Used in M60A1 Tank.

Temperatures

For any one design of weapon, ammunition component, or such, case ejection velocities normally vary with local ambient temperatures. To a certain degree, these velocities increase or decrease in direct relationship to the temperature. The limits in which this relationship holds true can be illustrated by the results of the extreme-temperature testing of the 105-mm gun M68 (Ref. 2a): in testing from +87° F downward to -65° F, the ejection velocities decreased as expected, but at +125° F, the ejection velocities were lower than at +87° F. Thus, there seems to be a critical point in the temperrature range for any particular type of case, chamber pressure, and weapon.

Bore Evacuation

Present tanks and some self-propelled weapons rely upon mechanical type bore evacuators to scavenge the bore gases from the tube after firing. Their efficiency depends a great deal on an uninterrupted flow of air and gases from the breech end toward the muzzle. Cartridge cases that fail to eject from the chamber block off this flow path and thereby decrease the bore evacuator's efficiency. When cases must be removed by manual means, propellant gases and fumes remaining in the case or chamber usually are forced back into the turret or cab, causing considerable discomfort, if not danger, to the gun crew. It is for this reason that positive case ejection is desirable.

Rate of Fire

When a case does not eject, a crew member must remove it before loading the next round. Obviously, this extra operation reduces the rate of fire and could be a serious problem during combat.

Breechblock Overtravel

If the cam design does not permit sufficient overtravel of the breechblock during the opening cycle, it will fail to lock open. When this happens, the cartridge case often will be caught by the reclosing breechblock and jammed between the block and chamber. Overtravel is normally controlled by the width of the cam (Fig. A-3).